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Nonlinear Dynamics Study Of Voltage Mode Controlled DC Drive With PID Controller

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ABSTRACT
This paper presents a non-linear dynamic model of a voltage controlled PMDC motor drive, based on the state vector analysis of the system is conducted. Proportional-Integral-derivative (PID) is the techniques proposed in this investigation to control the speed of a dc motor, revealing the periodic and chaotic phenomenon under different system parameter. Mathematical analysis and computer simulation are attached to verify the proposed non-linear model of the PMDC motor.
Keywords – Chaos, Non-linear, PMDC motor, Periodicity, Phase-plot

I. INTRODUCTION

Most power electronics circuit exhibit deterministic chaos and this may be responsible for unusual noise in some power electronics circuit, also belongs to the variable structure piecewise linear system. After each switching the system change their structure and the sequence of structures succeeds each other periodically in periodic steady state. The overall system are non-linear due to feedback controlled switching, hence the dependence of switching instants on state variable. In some cases nonlinearity is due to saturation or other nonlinearities. This Dissertation presents the detailed account on the control design of a buck converter driven PMDC motor in voltage controlled mode[1]-[3].Proportional-Integral-derivative (PID) are the techniques proposed in this investigation to control the speed of a dc motor. To control the speed there is a control loop which is a PID controller. The PID controller reduces the steady-state error, faster response, less oscillation, low overshoot and also increased the stability. The dynamic system composed from converter/motor is considered in this investigation and derived in the state-space and transfer function forms. Complete design and analyses of simulation results for PID technique are presented in time domain[16]. The output speed of the PMDC motor is compared with
a preset reference speed. The differences between these two signals are fed
as an error signal to the PID controller of the system. The output of the speed controller is the actuating signal that controls the operation duty cycle of converter. The converter output give the required input voltage Vin required to bring motor back to the desired speed. The results show that the voltage mode controlled dc drive system generally exhibit chaotic behavior. The occurrence of chaos as noisy or unstable operation of power electronic system without ignoring the switching effect, including dc-dc converter and dc drives, in industrial properties. For example the output motor speed and armature current fluctuation of dc drives may results from chaotic operation due to the change of system parameter[4].

II. DC DRIVE SYSTEM

A voltage mode buck-type dc chopper –fed permanent-magnet(PM)dc motor drive is targeted and investigate both numerically and analytically, the nonlinear dynamics and chaotic behaviour of industrial motor drives without ignoring the switching effect or accepting rough assumption. For investigation which forms the basis for investigation other industrial motor drives, to investigated the control of speed. As shown in Figure a voltage-controlled DC chopper-fed PMDC drive system operating in continuous conduction mode is used for exemplification. The corresponding equivalent circuit is shown in Figure where the motor speed v is controlled by constant frequency pulse width modulation (PWM).
Considering PID controller after comparing the reference speed and actual speed to minimizing the

error signal which is the control signal y(t) can be expressed as:

$$y(t) = k_p(\omega_{ref} - \omega) + \frac{k_p}{T_i}\int(\omega_{ref} - \omega) + k_d\frac{d}{dt}(\omega_{ref} - \omega) \quad (1)$$

Where (t) and ref are the instantaneous and reference motor speeds, respectively. The ramp voltage u(t) is represented by:

$$u(t) = v_l + (v_u - v_l)t/T \quad (2)$$

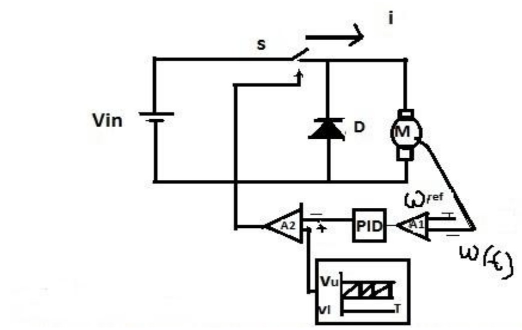

Fig 1:Schmetic diagram of DC Drive.

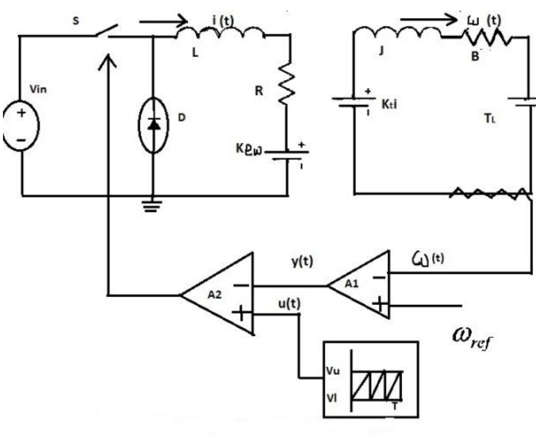

Fig 2: Equivalent circuit of DC Drive.

where vl and vu are, respectively, the lower and upper voltages of the ramp signal, and T is its period. Then, both y(t) and u(t) are fed into the comparator A2 which outputs the signal to turn the power switch S on or off.

When the control voltage exceeds the ramp voltage, S is off and hence the diode D comes on; otherwise, S is on and D is off. Thus, the system equation can be divided into two stages as given by:

STAGE1:

When y(t)<u(t) means switch is ON period.

STATE EQUIATION IS GIVEN BELOW:

$$\frac{di}{dt} = \frac{1}{L}(V_{in} - Ri_a - K_E\,\omega) \quad (3)$$

$$\frac{d\omega}{dt} = \frac{1}{J}(K_T\, i_a - B_\omega - T_L) \quad (4)$$

$$\frac{dy(t)}{dt} = -K_p\frac{d\omega}{dt} + \frac{K_p}{T_i}(\omega_{ref} - \omega) + K_D\frac{B}{J} \quad (5)$$

$$\frac{d}{dt}\begin{bmatrix} i_a \\ \omega(t) \\ y(t) \end{bmatrix} = \begin{bmatrix} \frac{-R}{L} & \frac{-K_E}{L} & 0 \\ \frac{K_T}{J} & \frac{-B}{J} & 0 \\ \frac{-K_{pK_T}}{J} & -K_p(\frac{B}{J} + \frac{1}{T_i}) & 0 \end{bmatrix}\begin{bmatrix} i_a \\ \omega(t) \\ y(t) \end{bmatrix} + \begin{bmatrix} \frac{1}{L} & 0 & 0 \\ 0 & \frac{-1}{J} & 0 \\ 0 & \frac{K_p}{J} & \frac{K_p}{T_i} \end{bmatrix}\begin{bmatrix} V_{in} \\ T_L \\ \omega_{ref} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \frac{K_D B}{J} \end{bmatrix} \quad (6)$$

STAGE 2:

When y(t)>u(t) means switch is OFF period.

STATE EQUIATION IS GIVEN BELOW:

$$\frac{di}{dt} = \frac{1}{L}(-Ri_a - K_E\,\omega) \quad (7)$$

$$\frac{d\omega}{dt} = \frac{1}{J}(K_T\, i_a - B_\omega - T_L) \quad (8)$$

$$\frac{dy(t)}{dt} = -K_p\frac{d\omega}{dt} + \frac{K_p}{T_i}(\omega_{ref} - \omega) + K_D\frac{B}{J} \quad (9)$$

$$\frac{d}{dt}\begin{bmatrix} i_a \\ \omega(t) \\ y(t) \end{bmatrix} = \begin{bmatrix} \frac{-R}{L} & \frac{-K_E}{L} & 0 \\ \frac{K_T}{J} & \frac{-B}{J} & 0 \\ \frac{-K_{pK_T}}{J} & -K_p(\frac{B}{J} + \frac{1}{T_i}) & 0 \end{bmatrix}\begin{bmatrix} i_a \\ \omega(t) \\ y(t) \end{bmatrix} + \begin{bmatrix} \frac{1}{L} & 0 & 0 \\ 0 & \frac{-1}{J} & 0 \\ 0 & \frac{K_p}{J} & \frac{K_p}{T_i} \end{bmatrix}\begin{bmatrix} V_{in} \\ T_L \\ \omega_{ref} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \frac{K_D B}{J} \end{bmatrix} \quad (10)$$

Where R is armature resistance, L armature inductance, Vin dc supply voltage, KE back-EMF constant, KT is torque constant, B viscous damping, J load inertia, and TL load torque.

III. SIMULATION RESULT

For a system possessing more than one unique behavior, as a parameter is varied, an abrupt change in the steady-state behavior of the system is called a bifurcation. Here we vary the amplitude of applied voltage. The voltage is varied from zero to 160 volt. The non-linear phenomenon in DC drive is observed as the input voltage is varied from 0 to 160 Volts. Figures have shown above represents the

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speed waveforms and the corresponding phase-portraits, at various periodic-speed operations, namely the period-1, period-2 and period-5 operations. The non-linear behaviors of the dc drive simulation study were carried out in MATLAB/SIMULINK environment. The rated parameters of the DC drive were: B=0.0000068 Nm/rad/sec, J=0.00035 Nms^2, $K_{E=}$0.215, $K_{T=}$0.215, $R_{a=}5\Omega$, $L_{a=}$0.0227 H,$T_{L=}$0.21 Nm, w_{ref} =100 rad/s, v_u=2.2, v_l=0, K_p=0.220, T_D=0.920, T_i=0.230, using this parameter value the results shows time and phase plotting with different input voltage.

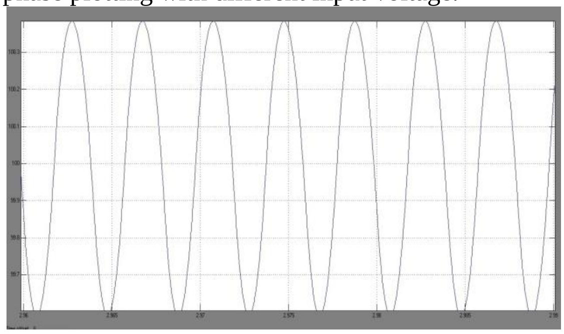

Fig 3(a):Speed waveform (period one)for 6o volts.

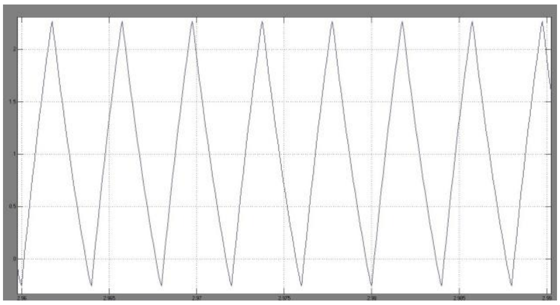

Fig 3(b):current waveform(period one)for 60 volts.

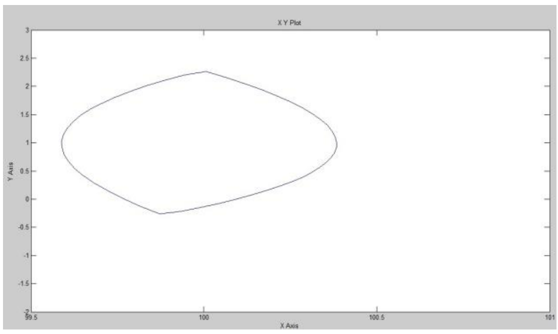

Fig 3(c):speed vs armature current for 60 volts.

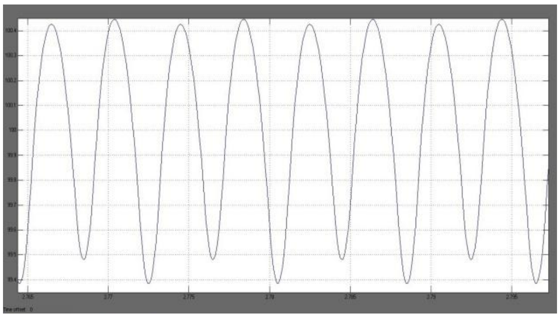

Fig 4(a):speed waveform (period two)for 90 volts.

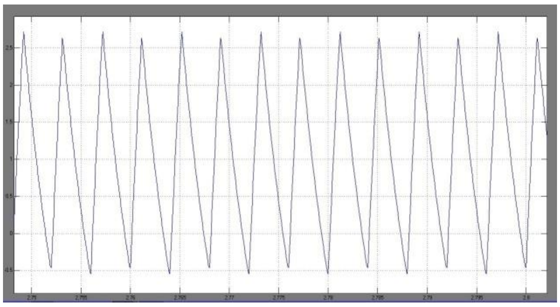

Fig 4(b):current waveform(period two)for 90 volts.

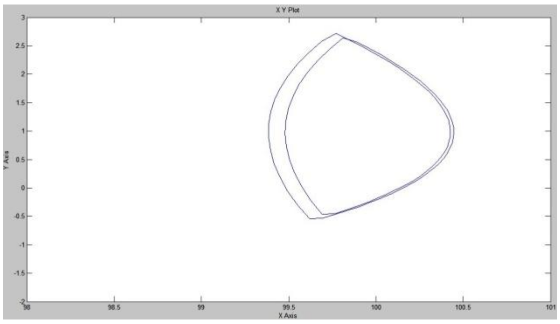

Fig4(c):speed vs armature current for 90 volts.

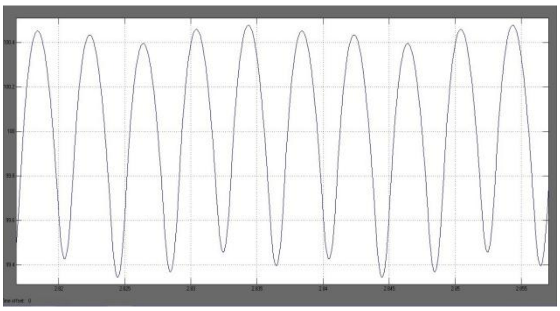

Fig5(a):speed waveform (period five)for 100 volts.

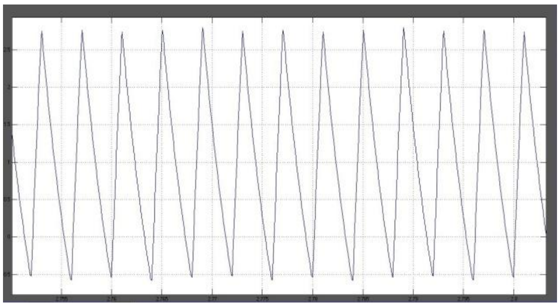

Fig5(a):armature current(period five)for 100 volts.

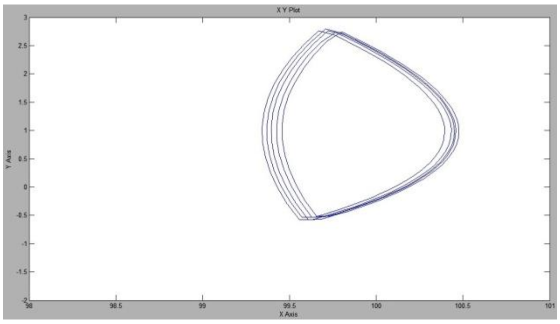

Fig5(c):speed vs armature current for 100 volts.

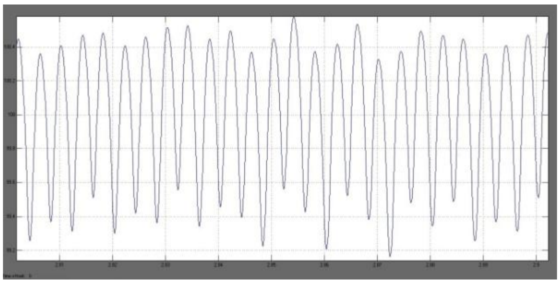

Fig6(a):Chaos speed for 105 volts.

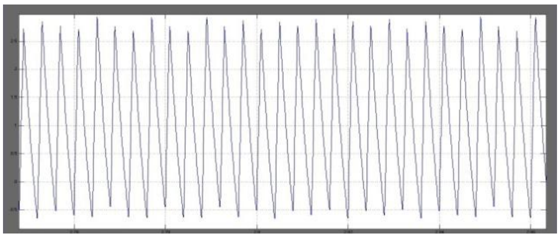

Fig 6(b):Chaos current for 105 volts.

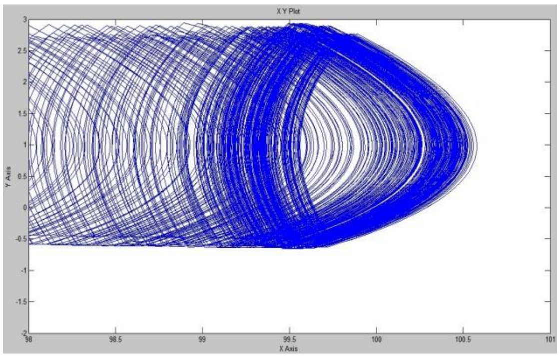

Fig 6(c):speed vs current for 105 volts.

IV. CONCLUSION

The non-linear phenomenon in Voltage mode controlled DC drive using PID controller are observed as the input voltages varied from 60 to 105 Volts. Figures have shown above represents the speed waveforms and the corresponding phase-portraits, at various periodic-speed operations, namely the period-1, period-2 and period-5 operations. Also the voltage 105 volts the speed and current response has unbounded periodicity, shown in phase portrait. Proposed approaches is the corresponding bifurcation analysis and also non-linear dynamics study of other converter fed dc drive

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